RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)		DATE February 2007

APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E

COST (In Millions)	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total Program Element (PE) Cost	127.893	145.239	152.622	156.242	159.959	160.596	161.617	166.596
Bio/Info/Micro Sciences BLS-01	44.652	41.166	42.635	48.926	54.925	55.925	62.946	66.925
Information Sciences CCS-02	18.373	26.930	29.567	30.627	28.314	27.951	26.951	27.951
Electronic Sciences ES-01	28.563	35.860	37.588	32.751	31.752	31.752	27.752	27.752
Materials Sciences MS-01	36.305	41.283	42.832	43.938	44.968	44.968	43.968	43.968

(U)   **Mission Description:**

(U)   The Defense Research Sciences Program Element is budgeted in the Basic Research Budget Activity because it provides the technical foundation for long-term National Security enhancement through the discovery of new phenomena and the exploration of the potential of such phenomena for Defense applications. It supports the scientific study and experimentation that is the basis for more advanced knowledge and understanding in information, electronic, biological and materials sciences.

(U)   The Bio/Info/Micro Sciences project will explore and develop potential technological breakthroughs that exist at the intersection of biology, information technology and micro/physical systems to exploit advances and leverage fundamental discoveries for the development of new technologies, techniques and systems of interest to the DoD. Programs in this project will draw upon information and physical sciences to discover properties of biological systems that cross multiple biological architectures and functions, from the molecular and genetic level through cellular, tissue, organ, and whole organisms' levels.

(U)   The Information Sciences project supports long term national security requirements through scientific research and experimentation in new computational models and mechanisms for reasoning and communication in complex, interconnected systems. The project is exploring novel means to exploit computer capabilities; enhance human-to-computer and computer-to-computer interaction technologies; advance innovative computer architectures; and discover new learning mechanisms and innovations in software composition. It is also fostering the computer science academic community to address the DoD's need for innovative computer and information science technologies.

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(U)   The Electronic Sciences project explores and demonstrates electronic and optoelectronic devices, circuits and processing concepts that will provide: (1) new technical options for meeting the information gathering, transmission and processing required to maintain near-real time knowledge of the enemy and the ability to communicate decisions based on that knowledge to all forces in near-real time; and (2) provide new means for achieving substantial increases in performance and cost reduction of military systems providing these capabilities.

(U)   The Materials Sciences project is concerned with the development of: high power density/high energy density mobile and portable power sources; processing and design approaches for nanoscale and/or bimolecular materials, interfaces and microsystems; materials and measurements for molecular-scale electronics and spin-dependent materials and devices.

(U)   Program Change Summary: *(In Millions)*

	FY 2006	FY 2007	FY 2008	FY 2009
Previous President's Budget	133.308	150.690	153.460	156.242
Current Budget	127.893	145.239	152.622	156.242
Total Adjustments	-5.415	-5.451	-0.838	0.000
Congressional program reductions	0.000	-13.501		
Congressional increases	0.000	8.050		
Reprogrammings	-2.000			
SBIR/STTR transfer	-3.415			

(U)   Change Summary Explanation:

FY 2006   The decrease reflects SBIR/STTR transfer and a reprogramming of the Infotonics Research congressionally added funding to the Army.

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FY 2007   The decrease reflects the net effect of congressional program reductions to Bio Interfaces, Computer Science Study Group, Carbon Nanotube RF Devices, Nanoscale/Biomolecular and Metamaterials, Spin Dependent Materials and Devices, and Section 8106 Economic Assumptions; offset by six congressional adds in the areas of Next-Generation Protective Gear, Genomics, Alternative Futures, Defense Research Scholars program, Drug Discovery and Development and Material research.

FY 2008   The decrease reflects very minor program repricing.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project BLS-01

COST (In Millions)	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Bio/Info/Micro Sciences BLS-01	44.652	41.166	42.635	48.926	54.925	55.925	62.946	66.925

(U)   **Mission Description:**

(U)   This project is investigating and developing the intersections of biology, information technology and micro/physical systems to exploit important technological advances and leverage fundamental discoveries for the development of new technologies, techniques, and systems of interest to the DoD. This research is critical to the development of rapid responses to engineered biological warfare agents, radically new biomolecular computers, and novel materials for the DoD. Programs in this project will draw upon the information and physical sciences to discover properties of biological systems that cross multiple scales of biological architecture and function, from the molecular and genetic level through cellular, tissue, organ, and whole organism levels. This project will develop the basic research tools in biology that are unique to the application of biological-based solutions to critical Defense problems. This project is also providing the supporting basic research for the effort to revolutionize prosthetics.

(U)   **Program Accomplishments/Planned Programs:**

	FY 2006	FY 2007	FY 2008	FY 2009
Bio Interfaces	3.900	5.000	7.960	10.925

(U)   The Bio Interfaces program will support scientific study and experimentation, emphasizing the interfaces between biology and the physical and mathematical/computer sciences. This unique interaction will develop new mathematical and experimental tools for understanding biology in a way that will allow its application to a myriad of DoD problems. These tools will help exploit the advances in the complex modeling of physical phenomena such as Electro-Magnetic Pulse (EMP) and blast with biological tissues and cells in order to understand and prevent the deleterious effects of traumatic brain injury. It is also expected that understanding the fundamentals of biology will aid in developing tools to understand complex, non-linear networks and force structures.

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(U)   Program Plans:
- Develop predictive biological models that take into account the materials and chemical properties of the brain to account for all blast effects including characteristics of the pressure wave, electromagnetic pulse, acoustics, etc.
- Exploit understanding of predictive blast/brain models to develop methods for preventing and treating traumatic brain injury due to blast.
- Demonstrate and validate novel mathematical tools for analyzing and interpreting complex data sets obtained from complex biological systems and behavior. Extend these tools to other problems of interest to DoD.
- Develop new mathematics that predict fundamental biological processes across biological size and time scales.

	FY 2006	FY 2007	FY 2008	FY 2009
Biological Adaptation, Assembly and Manufacturing	9.000	11.300	9.175	11.000

(U)   The Biological Adaptation, Assembly and Manufacturing program will examine the structure, function, and informational basis underlying biological system adaptation, particularly to harsh environments, and the factors employed by the organism to assemble and manufacture complex biological subsystems. The unique stability afforded biological systems in their ability to adapt to wide extremes of physical and endurance (e.g., heat, cold, and sleeplessness) parameters will be examined and exploited in order to engineer stability into biological systems required for the military (such as blood or other therapeutics). In addition, the fault tolerance present in biological systems will be exploited in order to assemble and manufacture complex physical and multi-functional systems, both biological and abiotic. Further activity in this area will investigate the adaptability of the brain to information processing and situational awareness. Applications to Defense systems include the development of chemical and biological sensors, and improved battlefield survivability of the warfighter.

(U)   Program Plans:
- Identify promising strategies in nature that allow organisms to survive under environmental extremes and adapt those strategies to other cells, tissues, organs and organisms, including platelets and red blood cells.
- Understand how cells differentiate/heal into functional tissues using naturally occurring mechanisms and adapt these naturally occurring mechanisms to develop the ability to replace scarring with fully regenerated tissue and structure at a wound site.

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− Determine which enteric bacteria that naturally occur in the gut can eliminate harmful bacteria and demonstrate that those bacteria can reduce the occurrence of diarrhea by 50%.
− Demonstrate the adaptation of bacteria to the digestion of cellulose in disaccharides to enable the ability to use fiber as nutrition and for the prevention of dysentery.
− Develop the fundamental understanding necessary to provide a single-step culture system that supports the differentiation of hematopoietic progenitor cells to mature megakaryocytes as a first step toward the reliable production of human blood products for battlefield use.

	FY 2006	FY 2007	FY 2008	FY 2009
Nanostructure in Biology	11.252	11.666	13.500	16.001

(U)   The Nanostructure in Biology program will investigate the nanostructure properties of biological materials to better understand their behavior and accelerate their exploitation for Defense applications. This new information about biomolecules will provide important new leads for the development of threat countermeasures, biomolecular sensors and motors, and molecular interventions to maintain human performance in the battlefield. This program will also develop approaches to mathematically predict, a priori, the structure of biological materials, especially proteins, based on the desired performance. This will enable the rapid design of new biosensors against previously unknown threats and the design of advanced catalysts based on biological activity to produce new materials of interest to DoD (e.g., tailored explosives). The program will also create technology to reliably integrate nanoscale and microsystems payloads on insects that will extract power, control locomotion, and also carry DoD relevant sensors. In addition, research will be conducted in the interaction, at the nanoscale, of biotic and abiotic materials and functions, a critical aspect in the development of advanced prosthetics.

(U)   Program Plans:
− Demonstrate image formation through the use of microchip-driven wire to simultaneously stimulate thousands of retinal neurons.
− Use nanostructured neural interfaces to develop an understanding of the neural information and algorithms used for biological visual processing (e.g., object recognition).

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- Demonstrate the ability to rapidly (hours as opposed to weeks or months) predict new protein structures that inactivate new biological pathogens or toxins.
- Demonstrate approaches for making enzymes that catalyze chemical reactions not performed by natural enzymes for the synthesis of chemicals of interest to the Department of Defense.
- Demonstrate locomotion control of insects using MEMS platforms consisting of ultrasonic projectors, pheromone ejectors, insect mechano-sensor activation, and visual presentation manipulation, neural, or muscular interfaces.
- Demonstrate power scavenging from insects via thermal-to-electric, and/or mechanical-to-electrical power conversion using embedded micro power generators.

	FY 2006	FY 2007	FY 2008	FY 2009
Human Assisted Neural Devices	12.000	12.000	12.000	11.000

(U)   This program will develop the scientific foundation for understanding the language of the brain for application to a variety of emerging DoD challenges, including improving performance on the battlefield and returning active duty military to their units. This will require an understanding of neuroscience, significant computational efforts, and new material design and implementation. Key advances expected from this research include the ability to improve decision making in a variety of DoD applications including imagery analysis. In addition, this thrust will provide an understanding of how the brain adapts as it learns. This understanding will be translated into improved training approaches that allow transition from novices to expert in military tasks such as marksmanship to be accomplished with minimum effort and time. Techniques will be examined to extract these signals non-invasively, which, if successful, will have pervasive impact to on-going efforts, including Revolutionizing Prosthetics (PE 0602715E, Project MBT-02).

(U)   Program Plans:
- Demonstrate that neural codes can control complex motor or sensory activity (e.g., reaching, grasping, manipulating, running, walking, kicking, digging, hearing, seeing, tactile) and that force and sensory feedback (positional, postural, visual, acoustic, and other) can be transferred back into the brain. Transition research to the Revolutionizing Prosthetics program.

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- − Explore new methods, processes, and instrumentation (e.g., Magnetoencephalography, optical, infrared, and radio frequency) for accessing neural codes non-invasively at appropriate spatiotemporal resolution to provide increased understanding of relationship between brain activity and function.
- − Identify robust neural signals that respond to visually salient objects and demonstrate that those neural signals can be used to significantly (3x) improve throughput in visual analysis tasks such as imagery analysis compared to using an individual's visuomotor transformation (i.e., movement) based response.
- − Investigate the underlying mechanisms of perception and cognition and use these to develop optimal approaches to radically improve neural plasticity in soldiers under stressful operational conditions.
- − Develop fundamental understanding of the neural basis of learning in order to accelerate transition from novice to expert in the warfighter operational environment.

	FY 2006	FY 2007	FY 2008	FY 2009
BioComputational Systems	3.000	0.000	0.000	0.000

(U)   The BioComputational Systems (BioCOMP) component used computation to understand the complexity of biology, and in turn used biology to enhance methods of computation. The BioCOMP program explored and developed computational models of bio-molecular processes in living cells that enabled a range of novel DoD capabilities for bio-agent threat assessment, force health protection, and bio-sensor design. The program also explored new biologically-inspired computing principles of robust information processing systems.

(U)   Recently developed genomic information models of complex gene-protein interactions have enabled simulation, dynamic analysis, prediction and control of cellular processes. Based on these models, the program has developed Bio-SPICE (Simulation Program for Intra-Cell Evaluation), an open software framework providing innovative models and analysis tools. The extensible design of Bio-SPICE allows for adding, refining and customizing of the Bio-SPICE models and tools for specific cell processes.

(U)   The program collaborated with several DoD client agencies including Defense Threat Reduction Agency (DTRA), U.S. Army Medical Research and Material Command (USAMRMC), Soldier Biological and Chemical Command (SBCCOM), Walter-Reed Army Institute for

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Research (WRAIR), Naval Medical Research Command (NMRC), the U.S. Air Force Toxicology program, and the Center for Disease Control and Prevention (CDC) for transition.

(U)   Program Plans:
– Developed a framework for describing and representing biological knowledge that spans data from the molecular (genomic, proteomic) to clinical level, and across organisms, to support deep and rapid knowledge extraction.
– Implemented cutting edge learning and reasoning algorithms that act on vast amounts of biological, experimental and simulation data; and demonstrated rapid reasoning and knowledge-acquisition.

	FY 2006	FY 2007	FY 2008	FY 2009
Simulation of Bio-Molecular Microsystems (SIMBIOSYS)	4.000	0.000	0.000	0.000

(U)   The Simulation of Bio-Molecular Microsystems (SIMBIOSYS) program developed methods and tools to simulate and design Bio-Molecular Microsystems to dramatically improve the interaction and integration of biological elements with synthetic materials. This was accomplished by exploring fundamental properties and compatibility of biological elements at the molecular surface level through experimental and theoretical analyses. Key phenomena under study included molecular recognition processes, signal transduction phenomena, and micro- and nano-scale transport of biological molecules. Engineering of biological systems was used to manipulate these fundamental characteristics and optimize the integration of biological elements with synthetic materials for information collection. Significant advancements in devices that utilize or mimic biological elements are being realized including sensors, computational devices and dynamic biological materials for force protection and medical devices.

(U)   Program Plans:
– Designed novel hybrid macro-molecular devices that form specific and controlled transducing functions at the molecular scale; demonstrated design of maltose binding proteins and ion channels with desired selectivity and sensitivity using computational tools.
– Designed and demonstrated working devices that incorporate biological elements as sensors, actuators and computational devices.

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	FY 2006	FY 2007	FY 2008	FY 2009
Drug Discovery and Development Initiative for National Security	0.000	1.200	0.000	0.000

(U)   Program Plans:
  −   Effort will attempt to find promising new methods for discovering drugs to enhance national security efforts.

	FY 2006	FY 2007	FY 2008	FY 2009
Biomedical Engineering Initiative	1.500	0.000	0.000	0.000

(U)   Developed technologies to enable Biomedical Engineering.

(U)   Other Program Funding Summary Cost:

•   Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project CCS-02

COST (In Millions)	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Information Sciences CCS-02	18.373	26.930	29.567	30.627	28.314	27.951	26.951	27.951

(U)   **Mission Description:**

(U)   This project supports scientific study and experimentation on new computational models and mechanisms for reasoning and communication in complex, interconnected systems in support of long-term national security requirements. The project is exploring novel means of exploiting computer capabilities; practical, logical and heuristic reasoning by machines; development of enhanced human-to-computer and computer-to-computer interaction technologies; innovative approaches to the composition of software; innovative computer architectures; and new learning mechanisms for systematically upgrading and improving these capabilities. Promising techniques will transition to both ongoing and system-level projects.

(U)   **Program Accomplishments/Planned Programs:**

	FY 2006	FY 2007	FY 2008	FY 2009
Computer Exploitation and Human Collaboration	18.373	22.357	22.631	22.951

(U)   The Computer Exploitation and Human Collaboration thrust supports research in broad areas of computational science having the potential for revolutionary advances in performance and other relevant metrics above and beyond extrapolations of current approaches. The research will yield significant advances in software, hardware, and computational systems that will allow warfighters and commanders of the future to interact in a natural way with computers, enable a new generation of collaboration methods and information acquisition, and provide intelligent seamless exchange of information in a world where computing devices are ubiquitous and heterogeneous. The thrust is exploring new human-machine interaction (HMI) paradigms where computing and communications systems reason about warfighter's and commander's goals and capabilities, and use this information to drive the interaction. Technical challenges include architectures for software agents; redesign of classical computer operating systems; secure exchange of information over insecure channels; robust, natural modes for increasing information and knowledge; and organizing both into easily retrievable, re-usable forms. Research is addressing breakthrough techniques for distilling key concepts from massive amounts of information and novel information presentation modes to provide concise, salient situational awareness. Work

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includes creation of powerful multi-agent systems and tools for effective decision-making and analysis in complex, multi-participant environments; high-performance, user-centered interfaces capable of understanding the warfighter and commander's combined natural communication and activity patterns; and fundamental technologies for integrating information expressed in different modalities and formats, which is currently a bottleneck to timely military situational awareness.

(U)   The Computer Exploitation and Human Collaboration thrust is exploring the fundamental science of interconnected systems to provide powerful mathematical tools for understanding the intrinsic properties and complexities of large-scale networks and other distributed systems. This foundational research is imperative for the future design of robust systems that break away from the established tradition of piece-meal patching of current infrastructures. The security of the nation depends on interconnected systems, such as data networks for the warfighter, the power grid, telecommunications systems, social and organizational networks, economic and financial systems and command and control structures. These networks can suffer dramatic failures. Such failures can potentially be prevented or controlled through a fundamental, quantitative understanding of the intrinsic properties of networks and development of mathematical tools. Additionally, deeper scientific foundations for what might be called "network understanding" will eventually generate dramatic new capabilities for the DoD while at the same time generating benefits for civilian applications. Overall, the research will provide vastly expanded power and improved interaction for a wide range of military tasks and environments. Currently the research is focused on the development of an overarching "Information Theory for Wireless Mobile Ad-Hoc Networks" (ITMANET). If this revolutionary kind of information theory can be developed, it will yield new mathematical tools applicable to other interconnected systems, offer practical guidance for developing the next generation of the DoD's wireless networks, and moreover provide insight concerning the acquisition and deployment of nearer-term systems.

(U)   Research on machine intelligence over the last two decades has revealed that many reasoning problems are inherently computationally complex, and in many cases, intractable. Solutions to these problems typically require either enormous computer resources, or simplification of the problem resulting in major sacrifices to accuracy. The Real-World Reasoning Thrust (REAL) is developing foundational technologies, heuristic approaches, and tools necessary to enable effective, practical machine reasoning about increasingly complex and large-scale problems. These technologies will aid commanders and warfighters in assessing the consequences of specific actions and strategies, and will help in predicting future results. The key technologies under investigation are effective, practical inferential reasoning in real-world situations with complexity and uncertainty; novel paradigms for learning while reasoning; integration of multiple reasoning paradigms; representation and reasoning with information that changes over time; reasoning about the goals of other agents; and appropriate metrics for measuring cognitive behavior and performance.

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(U)   Advanced research in innovative computer architectures is required to develop a new generation of unique processor designs and hardware architectures that exploit advances in ultra-high performance processing to support DoD applications. Mainstream commercial computer architectures are, by necessity, both incremental and constrained: incremental so that existing corporate investments are not threatened, and constrained so that legacy business applications continue to run on the latest computers. From a commercial perspective, this interactive design approach makes economic sense, but it has negative security ramifications. The DoD's increasing reliance on commercial hardware has had the unintended consequence of "leveling the playing field" with our adversaries. This effort will explore a new generation of processing architectures and critical functionality that could eventually provide revolutionary advances in processing capabilities, performance, and productivity thereby ensuring the U.S. continues to lead in computer architecture components that will form the foundations for the next wave of high performance embedded computing.

(U)   Another area of research will take a fresh look at the design and implementation of cognitive architectures modeled after human cognition, combining principles from neuroscience and cognitive psychology with traditional artificial intelligence-based symbolic processing and knowledge representation. These efforts will draw on advances in neurophysiology and cognitive psychology to guide and augment traditional artificial intelligence (AI) approaches to learning, reasoning, memory, knowledge acquisition and organization, and executive functions. Designing software inspired by the brain's processing schemes can offer leap-ahead advances in cognitive systems. This work has the potential to revolutionize a broad range of military applications through breakthrough performance of intelligent machines.

(U)   Program Plans:
 – Developed new machine learning algorithms that resulted in effectively doubling performance of personal cognitive assistants.
 – Developed breakthrough technologies for multiple learning algorithms to share information and exchange training data even when the learning algorithms' models are represented differently and potentially inconsistent.
 – Developed methods for combining statistical and knowledge-based reasoning and learning algorithms.
 – Defined fundamentally new computational models for reasoning, learning, memory and perception based on integrating recent scientific insights from neuroscience and cognitive psychology, plus mathematics and computer science.
 – Derived a new theory of natural intelligence that is a hybrid of analog and digital processing in the brain.
 – Developed adaptive multimodal processing techniques tailored to the user, task, and environment; and assessed performance and usability advantages within multimodal systems.

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- Demonstrated, on problems of limited scope, a new learning-based algorithm that achieves a 10^9 speed-up in logical QBF (quantified Boolean formulae) reasoning.
- Demonstrated, on small problems, new reasoning algorithms that combine pruning, consistency models, and statistical sampling to decide on a course of action even when the state of the world is unknown.
- Determined, on small problems, that Nash equilibrium points could be identified in multi-party, mixed tactical/strategic settings, determining which action a commander should take and with whom to partner in a given situation.
- Initiated work by two university research teams to develop a revolutionary information theory for mobile ad-hoc networks (ITMANET) that will provide theoretical underpinnings and performance goals/limits for the next generation of DoD wireless networks as well as practical guidance for the acquisition and deployment of near-term systems.
- Assessed the state of the high performance computing independent software vendor (ISV) industry, surveying public and the private sector entities to determine the specific actions that can be taken to expand ultra-high performance computing usage across the private sector for national competitive gain, including the major drivers for usage, barriers and actions that can be taken to mitigate those barriers.
- Develop innovative algorithms for dramatically reducing the complexity and processing required for reaching conclusions in logical reasoning systems where the problems are of an operationally realistic scale and complexity.
- Develop reasoning algorithms that can analyze situations and decide on effective courses of action even when the exact state of the world is unknown (aka partial observability) on problems of realistic size and complexity.
- Develop strategic reasoning algorithms that analyze complex, multi-party, mixed tactical / strategic settings (like those found in modern warfare situations), and provide decision support to warfighters about who is partnered with whom and what posture might be taken with respect to these parties; where the problems are of realistic size and complexity.
- Develop an information theory for mobile ad-hoc networks that incorporates inherent system dynamics, multi-hop interactions, multi-user channels, protocol overhead, side information and feedback.
- Derive capacity limits for mobile ad-hoc networks using throughput-delay-reliability curves.
- Develop information-theoretic models for mobile ad-hoc networks employing emerging cooperative and distributed networking techniques.
- Establish multidisciplinary studies of large-scale interconnected systems drawn from the fields of information theory, complexity theory, adaptive systems, diffusion theory, group theory and social network analysis.

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− Identify and evaluate non-conventional, revolutionary processing architectures to pursue breakthrough advancements in processing, performance, and productivity.
− Develop concepts for, and evaluate the feasibility of computational architectures and computing systems that monitor execution at run time, and dynamically optimize performance (e.g., with respect to caching, on-chip packet routing, etc.) on common applications.
− Provide program planning support for the DARPA Urban Challenge.

	FY 2006	FY 2007	FY 2008	FY 2009
Computer Science Study Group (CSSG)	0.000	4.573	6.936	7.676

(U)   The Computer Science Study Group (CSSG) program funds emerging ideas from the computer science academic community to address the DoD's need for innovative computer and information science technologies; educate young principal investigators; acclimate a generation of researchers to the needs and priorities of the DoD, and enable the transition of those ideas and applications by promoting joint university, industry, and government projects. The CSSG project formalizes and focuses this research for efficiency and greater effectiveness.

(U)   Program Plans:
− Establish a Computer Science Study Panel (CSSP) consisting of mentors from senior academic and military communities.
− Arrange seminars for CSSP participants, at sites around the country where participants can experience DoD computer and information science capabilities and shortcomings.
− Evaluate and approve proposals for major university research projects to conduct basic computer and information science and technology research, based on knowledge gained in CSSP meetings.
− Solicit co-funding from industry or interested government parties to continue successful university research projects.
− Develop a transition strategy with university participants and co-funding sources.

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(U)   **Other Program Funding Summary Cost:**

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project ES-01

COST (In Millions)	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Electronic Sciences ES-01	28.563	35.860	37.588	32.751	31.752	31.752	27.752	27.752

(U) **Mission Description:**

(U)   This project seeks to continue the phenomenal progress in microelectronics innovation that has characterized the last decades by exploring and demonstrating electronic and optoelectronic devices, circuits and processing concepts that will: 1) provide new technical options for meeting the information gathering, transmission and processing required to maintain near real-time knowledge of the enemy and the ability to communicate decisions based on that knowledge to all forces in near real-time; and 2) provide new means for achieving substantial increases in performance and cost reduction of military systems providing these capabilities. Research areas include new electronic and optoelectronic device and circuit concepts, operation of devices at higher frequency and lower power, extension of diode laser operation to new wavelength ranges relevant to military missions, development of uncooled and novel infrared detector materials for night vision and other sensor applications, development of innovative optical and electronic technologies for interconnecting modules in high performance systems, research to realize field portable electronics with reduced power requirements, and system and component level improvements to provide greater affordability and reliability. Additionally, electronically controlled microinstruments offer the possibility of nanometer-scale probing, sensing and manipulation for ultra-high density information storage "on-a-chip," for nanometer-scale patterning, and for molecular level analysis and synthesis. These microinstruments may also offer new approaches to integration, testing, controlling, manipulating and manufacturing nanometer-scale structures, molecules and devices.

(U) **Program Accomplishments/Planned Programs:**

	FY 2006	FY 2007	FY 2008	FY 2009
University Photonic Opto-Centers	9.000	6.452	2.010	0.000

(U)   This program is dedicated to coupling university based engineering research centers of excellence with appropriate industry groups to conduct research leading to development of advanced optoelectronic components. Such components are critical to enhancing the effectiveness of military platforms that provide warfighter comprehensive awareness and precision engagement. Topics researched include emitters, detectors,

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modulators and switches operating from infrared to ultraviolet wavelengths, and related heterogeneous materials processing and device fabrication technologies for realizing compact, integrated optoelectronic modules. The University Photonic Opto-Centers Phase II program will facilitate and enhance interaction between the developers of cutting edge photonic device technology in the industry and academic researchers that exploit these devices for novel applications. Commercially co-funded, industrial participants benefit by getting feedback from potential users of their device technology as well as by ensuring that the graduates are trained in the latest device technologies.

(U)   Program Plans:
- Evaluate novel methods for the design, fabrication and demonstration of chip-scale modules that integrate photonic, electronic and MEMS based technologies.
- Characterize the impact of these new technologies on applications in the areas of bio-photonics, optically addressed memory and on-chip optical interconnects.
- Fabricate and test individual chip-level sub-assemblies for later use in prototype development.
- Design and fabricate prototype modules using the system-on-a-chip approach.
- Develop testbeds capable of fully measuring and characterizing the mixed technologies implemented in the chip-scale components.
- Evaluate the performance characteristics of the prototype modules and determine the highest payoff dual use development paths.
- Identify and enlist industrial participants.
- Identify a common set of photonic devices most widely used/requested and make them immediately available for experimentation.

	FY 2006	FY 2007	FY 2008	FY 2009
Semiconductor Technology Focus Centers	10.000	10.000	10.000	10.000

(U)   The Semiconductor Technology Focus Center Research program concentrates on exploratory and fundamental semiconductor research efforts that solve the most critical, long-term scaling challenges in the fabrication of high performance complex integrated circuits. This program will develop new design and fabrication approaches and will demonstrate technologies for reaching nano-scale device dimensions and hyper-scale integrated circuits that will meet future military needs. The Young Faculty Award (YFA) program will fund several 12-month research efforts focused on innovations that enable revolutionary advances in physics, materials, and devices.

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(U)   Program Plans:
- Develop efficient platform-based design methodologies and low latency interconnect technologies for complex integrated circuits that have application in high performance signal processing and communications systems.
- Develop methods for physics-based simulations of performance of deeply scaled switching device structures and circuit architectures.
- Develop the interface methodology for efficient handling and compilation of design object information for complex military integrated circuits.
- Develop circuit architectures that reduce long interconnects.
- Develop novel device fabrication and integration approaches for deeply scaled transistors and architectures for high performance mixed signal circuits for military needs.
- Develop concepts and validation methods in one or combinations of the following areas: electronics, photonics, micro-electro-mechanical systems (MEMS), architectures and algorithms under the Young Faculty Award imitative.

	FY 2006	FY 2007	FY 2008	FY 2009
Molecular Photonics (MORPH) (formerly Supermolecular Photonics Engineering)	6.240	8.060	8.000	2.000

(U)   Large dendritic and other highly branched organic molecules offer great potential for active photonic applications. Three-dimensional molecular structure and shape can be engineered to orient and immobilize optically active substituents to achieve much higher electro-optic activity than with traditional polymer systems. The ability to engineer molecular structure, shape, energy transport, and chemical composition offers the potential for distinct electronic energy level engineering without the traditional semiconductor crystal lattice. This will allow more freedom to tailor electromagnetic responses of individual molecules to achieve functionality not possible in semiconductors. Potential applications include: direct conversion of sunlight to power ("optical antenna"), inversion-less lasers and electromagnetically induced transparency (coherent organic emitters, and slow light materials), high performance photorefractive materials for signal processing and holographic memory, optical limiters and saturable absorbers as well as high performance modulators.

(U)   Program Plans:
- Model and simulate advanced structures for four classes of applications.

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− Improve modeling capability for predicting macro functionality from nanostructure.
− Emphasize chemical synthesis.
− Address parameters such as thermal stability, environmental chemistry tolerance (O_2, H_2O, etc) and photochemistry.
− Fabricate initial devices; continue modeling maturation.
− Final material synthesis, prototype device fabrications, characterization and demonstration.

	FY 2006	FY 2007	FY 2008	FY 2009
Photonics Technology Access Program (PTAP)	3.323	1.300	0.000	0.000

(U)   The main goal of the Photonic Technology Access Program (PTAP) is to create a mechanism for providing the latest prototype optoelectronic devices and custom materials to systems researchers. The program seeks to build bridges between the device and systems research community, the university and industrial community and the teaching and research community.

(U)   Program Plan:
− Employed a broker-supplier user model that has been previously tried for integrated circuits and micro-electro-mechanical systems to implement the program.
− Evaluated the number of device/material transactions implemented between users and suppliers.

	FY 2006	FY 2007	FY 2008	FY 2009
Quantum Entanglement Science and Technology (QuEST)	0.000	2.059	5.000	5.812

(U)   The Quantum Entanglement Science and Technology (QuEST) program will explore the research necessary to create new technologies based on quantum information science. Technical challenges include loss of information due to quantum decoherence, limited communication distance due to signal attenuation, protocols, and larger numbers of quantum bits (Qubits) and their entanglement. A key challenge is to integrate improved single and entangled photon and electron sources and detectors into quantum computation and communication networks. Error

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correction codes, fault tolerant schemes, and longer decoherence times will address the loss of information. Expected impacts include highly secure communications, algorithms for optimization in logistics, highly precise measurements of time and position on the earth and in space, and new image and signal processing methods for target tracking.

(U)   Program Plans:
  –   Explore the fundamental quantum systems including entanglement, decoherence, multipartite quantum systems.
  –   Develop novel algorithms and protocols germane to quantum information science.
  –   Investigate small quantum systems.

	FY 2006	FY 2007	FY 2008	FY 2009
MEMS Science and Focus Centers	0.000	7.989	9.486	8.771

(U)   The MEMS Science and Focus Centers effort is seeking research by means of multi-performer (university/nonprofit/industry/other) focus centers dedicated to advancing a number of core technologies considered essential to the advancement of MEMS and Nano-Electro-Mechanical Systems (NEMS) technology for applications important to the Department of Defense (DoD). The fundamental technology areas of interest for the program are: Surface Physics, Noise Mechanisms, Reliability Physics, Scaling Physics, Microfluidics, Interconnections, Single-Molecule Methods, Modeling, Signal Processing Methods, and other areas.

(U)   Program Plans:
  –   Develop a fundamental understanding of the behavior of materials interfaces and associated reliability.
  –   Fabricate non-lithographic MEMS.
  –   Develop an understanding of fluidics on a nanoscale.
  –   Develop MEMS enabled reconfigurable electronics.
  –   Develop ultra-high Q nanoresonators.

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	FY 2006	FY 2007	FY 2008	FY 2009
Semiconductor A1GaN Injection Lasers (SAIL)	0.000	0.000	1.092	3.168

(U)   The objective of SAIL (Semiconductor AlGaN Injection Lasers) is to demonstrate lasers with ultraviolet emission in the wavelength range of 340 to 270 nm. These lasers will be based on heterostructures of Aluminum Gallium Nitride (AlGaN). Such lasers do not exist at present. Once demonstrated, SAIL devices are expected to have applications in stand-off biodefense, such as point detection of aerosolized bio agents.

(U)   Program Plans:
   ‒   Develop methods for preparing AlGaN with low density of dislocations.
   ‒   Demonstrate effective p-type doping in AlGaN with the AlN content of 60%.
   ‒   Fabricate injection lasers operating in the ultraviolet at 340 nm and 280 nm.
   ‒   Demonstrate stable and reliable operation of ultraviolet lasers at room temperature.

	FY 2006	FY 2007	FY 2008	FY 2009
Nanoscaled Architecture for Coherent Hyper-Optic Sources (NACHOS)	0.000	0.000	2.000	3.000

(U)   This program will explore scaling rules for semiconductor laser sources. Such rules exist and are well understood in electronics but do not yet exist for photonic devices. Nanoscaled lasers would be useful in a wide range of applications, from close integration with electronics, on chip light sources, to single photon sources. The program idea is based on recent developments in heterostructured semiconductor nanowires (the gain medium), which establish the feasibility of forming lasers with diameters much smaller than the wavelength of light they produce. Simultaneously, advances in plasmonic structures, which support optical frequencies with x-ray like wavelength, make it possible to envision feedback structures (cavities) that are also shorter than the wavelength of light emitted from the cavity. The program goal will thus be to produce nanoscaled lasers with all three dimensions shorter than the wavelength of light. Important issues of beam shaping through antenna-like structures and powering via plasmonic structures will also be considered.

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(U) Program Plans:
-   Develop defect-free nanowire-based heterostructures.
-   Grow lithographically defined nanowire heterostructures.
-   Use photonic bandgap structures for feedback and coupling of light.
-   Establish and validate models for nanophotonics.

(U) Other Program Funding Summary Cost:

•   Not Applicable.

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COST (In Millions)	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Materials Sciences MS-01	36.305	41.283	42.832	43.938	44.968	44.968	43.968	43.968

(U)   **Mission Description:**

(U)   This project provides the fundamental research that underpins the development of advanced nanoscale and bio-molecular materials, devices and electronics for DoD applications.

(U)   **Program Accomplishments/Planned Programs:**

	FY 2006	FY 2007	FY 2008	FY 2009
Nanoscale/Biomolecular and MetaMaterials	11.000	12.000	15.057	17.500

(U)   The research in this thrust area exploits advances in nanoscale and bio-molecular materials, including computationally based materials science, in order to develop unique microstructures and properties of materials. This includes efforts to develop the underlying physics for the behavior of materials whose properties have been engineered at the nanoscale (Metamaterials) level.

(U)   Program Plans:
 − Develop algorithmic approaches for predicting properties and structure of nano-scale and meta-materials using first principles/quantum mechanical methods with higher accuracy and reduced computational complexity.
 − Couple the algorithmic approaches to methods that extract parameters for simulation of materials at larger spatial scales while conducting experiments to verify/validate the predicted properties at all spatial scales.
 − Explore and exploit the underlying dualities between discrete and continuous computational methods to dramatically improve DoD computational abilities.
 − Develop theoretical advances to characterize the propagation of random effects through differential equation models of electromagnetic material systems to allow interpolation, extrapolation, and hybridization of solutions to known systems to closely related "perturbed" systems.

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- Develop nanoscale material concepts (nano-generators) for harvesting available mechanical energy from a soldier's body and surrounding environment and convert it into usable electrical energy for micro sensors and devices such as chip scale atomic clocks (CSACs) or micro gas analyzers (MGAs).
- Develop nanotechnologies to enable the capability for low power, portable, nanoscale surface manipulation and nanoscale surface metrology for the purpose of encoding information on a wide variety of common surfaces.
- Develop advanced image detector materials to instantly and simultaneously detect one structural (computed tomography) and two functional (position emission tomography and single photon emission tomography) images of medical and life science interest.
- Demonstrate materials capability to allow multimodal imaging system with two orders of magnitude increased scan speed and detection for non-destructive testing and evaluation.
- Develop approaches for exploiting femtosecond laser pulses to generate multi-spectral imaging capable of examining nanostructured materials.
- Exploit nanotechnology to create a new class of previously inaccessible compositions for optical materials, including IR windows and transparent armor.

	FY 2006	FY 2007	FY 2008	FY 2009
Engineered Bio-Molecular Nano-Devices and Systems	8.155	10.433	12.775	11.000

(U)   This program seeks to develop and demonstrate engineered bio-molecular nano-scale devices that enable real time observation and analysis of bio-molecular signals, thus enabling single molecule sensitivity with the simultaneous exploitation of the temporal domain (i.e., stochastic sensing). Arrays of such devices will enable an order of magnitude (10 to 100X) reduction in the time required for analysis and identification of known and unknown (engineered) molecules.

(U)   Program Plans:
- Engineer hybrid biological/inorganic device architectures that optimize compatibility and information transfer between biological and non-biological materials with single molecule sensitivity.
- Develop new and innovative technologies in the areas of device architecture, design, interconnection, fabrication and integration of organic and inorganic materials to enable measurement of time constants of single molecule events.

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−   Develop techniques to perform direct, dynamic, stochastic and combinatorial analysis of bio-molecular signals in order to characterize unique molecular signatures based on such analysis (i.e., automatic recognition) of various biological/chemical targets.

	FY 2006	FY 2007	FY 2008	FY 2009
Atomic Scale Materials and Devices (formerly Spin Dependent Mats. and Devices)	12.000	12.000	15.000	15.438

(U)   This thrust examines the fundamental behavior of the physics of materials at the atomic scale in order to exploit this behavior for new devices and capabilities. A major emphasis of this thrust is to provide the theoretical and experimental underpinnings of a new class of semiconductor electronics based on spin degree of freedom of the electron, in addition to (or in place of) the charge. Not only will this class of electronics lead to novel and faster electronic devices, but it will also serve as one of the key technology enablers for quantum communications and quantum computation. In addition, this program will examine other novel classes of materials and phenomena such as plasmons or Bose-Einstein Condensates (BEC) that have the potential to provide new capabilities in the quantum regime.

(U)   Program Plans:
−   Demonstrate a variety of spin related devices such as a room temperature spin light emitting diode (LED), a spin transistor with significant gain and magnetic random access memory scaled down into the few nanometer bit size by replacing magnetic field switching with spin momentum transfer switching.
−   Develop new storage class memories with 100 – 1000 times the density of MRAM, DRAM or FLASH using magnetic domain walls as the storage media and spin momentum transfer as the read and write protocol.
−   Investigate the magnetic and electronic characteristics of surface plasmons for the creation of metal/dielectric interfaces for coupling between photonic and electronic/spin states.
−   Demonstrate atom-chip BEC lifetimes of >100ms and quasi-continuous BEC with 2000 atoms/pulse and >20% duty cycle.
−   Demonstrate rotationally sensitive atom interferometer using optical readout in magnetic waveguides; establish sensitivity.
−   Develop an optical lattice emulator (OLE) of strongly correlated systems to enable a new approach to the design of technologically important materials (e.g., high-temperature superconductors and ferromagnetic semiconductors), and serve as an early platform for synthesis of novel exotic states of matter (e.g., supersolids).

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- − Develop fundamental technologies to enable a compact all-optical clock, including the frequency standard and associated electronics, that would produce a time output with accuracy and stability in excess of any transportable clockwork currently in existence.
- − Explore fundamental behavior of nanostructured materials that display quantum and/or non-equilibrium behavior.

	FY 2006	FY 2007	FY 2008	FY 2009
Comparative Genomics for National Security Goals	1.500	1.650	0.000	0.000

(U) Program Plans:
- − Develop new approaches for examining prognostic epidemiology using comparative genomics.

	FY 2006	FY 2007	FY 2008	FY 2009
Advanced Materials for Quantum Computing	2.650	0.000	0.000	0.000

(U) Program Plans:
- − Developed materials that enabled the instantiation of quantum computing concepts.

	FY 2006	FY 2007	FY 2008	FY 2009
PBO	1.000	0.000	0.000	0.000

(U) Program Plans:
- − Researched the application of PBO (Polyphenylene benzobisoxazole) in the development of non-flammable and lightweight materials.

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	FY 2006	FY 2007	FY 2008	FY 2009
Advanced Materials Research Institute	0.000	2.200	0.000	0.000

(U) Program Plans:
- This effort will focus on the development and demonstration of hybrid sensors for chemical and/or biological agent detection for national security. In particular, sensors made from metal oxide nanoparticles and nanowires will be explored.

	FY 2006	FY 2007	FY 2008	FY 2009
Next Generation Protective Gear for Small Arms Threats	0.000	1.000	0.000	0.000

(U) Program Plans:
- Explore next generation protective gear for small arms threats.

	FY 2006	FY 2007	FY 2008	FY 2009
Alternative Futures at the Range-Complex Level for the Southwest U.S.	0.000	1.000	0.000	0.000

(U) Program Plans:
- Explore alternative Range-Complex Level Futures in the Southwestern part of the U.S.

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	FY 2006	FY 2007	FY 2008	FY 2009
John H. Hopps Defense Research Scholars Program	0.000	1.000	0.000	0.000

(U)   Program Plans:
 −   Support the John H. Hopps Defense Research Scholars Program.

(U)   Other Program Funding Summary Cost:

•   Not Applicable.